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February 11, 2021

Mr. James Johnston
Tennessee Department of Environment and Conservation
312 Rosa L. Parks Avenue
Nashville, TN 37243

Dear Mr. Johnston,

Please see enclosed documents regarding a test plan for emissions permitting data for Volunteer Environmental Services (VES) in Covington, TN.

As a basic principal, solid organic materials do not combust in their physical state as a solid. Rather, solid incinerators burn a film of gas that emanates from the solid surface once the solid has been heated to a state of molecular instability. The process is perpetuated as the heat from the burning film of gas sustains the molecular instability of the solid until it is nearly completely evaporated. The second requirement of solid fuel incineration is supplying sufficient supplemental oxygen to sustain the combustion of the gas film around the solid. This is where direct incineration becomes problematic. To ensure oxygen flow from the surrounding hot environment into the combusting film, a significant amount of turbulence is needed, which has the unwanted side-effect of fluidizing residues and non-combustible constituents of the solid fuel. This most always translates into carryover of ash and soot into downstream equipment, into the flue stack gases, and out into the environment. Consequently, costly equipment must be installed to capture these particulates and mitigate there release to the best extent achievable.

An alternate approach to direct incineration involves a concept that easily dates back to the early 1900's and has even been highly-promoted by the USEPA as a preferred technology for combustion of solid phase fuels. This process first brings the solid to thermal instability under a controlled, near laminar-flow gas phase passing through the solid. This approach to combustion fundamentally reduces or nearly eliminates the turbulent forces that would otherwise fluidize and transports these residues and non-combustible solids into the flame environment. In essence, gasification as a pre-step separates the "gas film" from the solid fuel and subjects only these gases to the turbulent air regime required to completely combust the fuel. This approach has been widely used in recent decades as a much better means for using solid fuels for energy release. The primary impediment to wide-scale adoption of this approach to combustion has been that industrial-grade

equipment that can withstand the thermal rigors of the gasification pre-step have been difficult to attract capital investment. Many projects in the past have failed because the gasification equipment can only run stably under tightly-controlled conditions, and even then, some have required frequent and costly maintenance cycles to sustain their operation.

Around 2010, our investors and research engineering team decided to develop industrial-grade gasification equipment that was not plagued by the maintenance and control issues of the past and that used a new generation of materials that could withstand long-term the thermal rigors of the gasification pre-step. As additional design features, we decided to make as wide a range of solid organic materials as suitable feedstock and to make it scalable so as to ensure that its usefulness would be attractive to largest possible marketplace. The platform we chose was the Downdraft Gasifier concept, which was extensively studied by the EPA in the 1970's. After 6 or so years of concept-to-commercialization effort, our team placed the first industrial, high-performance downdraft gasifiers in Gleason, TN at the Boral Brick facility. Six of these gasification reactors were installed in parallel to produce a combustible fuel gas from woodchip to offset natural gas usage in the brick kiln. Subsequent to that project, the 7th reactor was built in Covington, TN and the 8th unit, the largest downdraft gasifier in the World, is currently operating outside of Nashville.

Over the years of this commercialization effort, we have tested a wide range of solid and liquid fuel types ranging from oil-field waste liquids, agricultural crop residues, spent rubber tires, and construction debris. As scientists, what we learned is that most any material that is comprised of C-H or C-H-O (i.e., hydrocarbon or organic) become thermally unstable at a certain point. Therefore, with a baseline of chipped wood waste as the substrate, many other types of problematic wastes could enter the reactor and be molecularly decomposed along with the woodchip. As you know, this concept was successfully demonstrated in the Covington facility as we injected a controlled-rate of dewatered sewage sludge into the unit along with the woodchip baseline. And, we successfully conducted at least 2 different emissions studies on this blend of solid materials. The concept of a woodchip baseline plus a second solid that is very difficult to combust was also proven successful and permissible for blends of chip and chunk rubber tire in AL.

The concept that VES noticed very early on was that, like sewage sludge, some materials are more problematic to dispose by landfill. As you probably know, landfilling is a version of biological gasification that is spread-out over many years and leaves a concentrated residue that can be environmentally toxic for many centuries after the organics have evaporated away. Moreover, the emanating biogases simply enter the surrounding air and potentially pose an even greater environmental risk.

Medical wastes clearly present their own host of problems with landfilling. However, by first establishing stable gasifier operation on woodchip and then introducing a controlled-rate of medical waste into the unit, the organic content therein can be safely decomposed into combustible elemental gases, whose residual energy content can further be used to generate electricity. In my opinion, this approach is by far a better solution than landfilling these types of wastes. We have already conducted short-run tests of the type of medical wastes VES sources and have seen no adverse reactions to the gasifier stability when operating on a blend with chipped wood waste.

A study published by the Cambridge University press in 2016 determined that hospital waste is consisted of:

- 99.02% combustible wastes and 0.97% noncombustible wastes by mass.
- Waste constituents:
 - Paper (16.17%),
 - Textiles (9.77%),
 - Cardboard, wood, and leaves (1.12%),
 - Food waste (21.5 1%),

- Plastics (50.45%).
- Metal and Noncombustible waste (0.40%), and
- Glass (0.57%)
- Proximate Analysis (wt. %)
 - Moisture (38%),
 - Ash (4%)
 - C-H-O (58%)
 - C-H (43%)
 - O (15%)
 - HHV 6,115 Btu/lb.

Chipped wood waste from the Covington area during the last Emissions Test plan conducted at the site showed:

- Proximate Analysis (wt.%)
 - Moisture (46.3%)
 - Ash (2.2%)
 - C-H-O (51.5%)
 - Sulfur (0.04%)
 - HHV 5,368 btu/lb.
- Ultimate Analysis (wt.% dry)
 - C-H-O (95.5%)
 - Ash (3.8%)
 - Nitrogen (0.6%)
 - Sulfur (0.07%)

As you can see, chemically speaking, the medical waste is not all that different than the wood waste. Medical waste has a slightly higher HHV due to its higher ratio of Carbon to Oxygen, resulting from the presence of plastics (hydrocarbon). Our experience has shown this level of difference is relatively minor to how they decompose inside the gasifier. The largest dictator to stability of gasifier operation is by far the total moisture content. This is why we designed the Covington facility with a woodchip dryer to reduce the natural moisture content of green wood waste prior to entering the gasifier.

The VES proposed test plan will be as follows:

1. Mobilize Test Team to site and function test each piece of unit equipment and instrumentation and make any necessary repairs to ensure reliable operation of all critical parts and communication with the SCADA control system (Step time: 1-2 days depending on current conditions of the system).
2. Clean and inspect the gasifier unit and ceramics to confirm suitability for operation (Step time: 1 day).
3. Determine the wood weight rate on each feed cycle by collecting, weighing and averaging at least 3 fill dumps using a catch bucket. Adjust conveyor run-time to charge around 40-50 lbs. of chip per fill cycle.
4. Establish stable gasifier operation on woodchip at a rate of around 8 tons per day. Allow producer gas temperature exiting the gasifier to reach steady-state for at least 6-8 hours (Step time ~10-12 hours). Maintain oxidizer temperature above 1,750°F and a minimum of 5% excess O₂.

5. Begin adding one individually sealed Medical Waste bag by hand into every other woodchip feed tube during each batch feed cycle, record the weight of each bag added by placing a scale up on the feed deck (Step time: 4-6 hours). Confirm that the feed auger is not jamming by the whole bags being placed in with the chip charges. Medical waste rate should be around 6.5% of total feed weight rate. (auger should have enough torque to shred the bags and blend with the incoming chip).
6. Confirm reactor stability, then begin increasing Medical Waste bag addition rate to one or more bags each feed cycle recording weights and times of each bag addition. If unit feed calls begin to decline, incrementally decreasing woodchip rate fill rate and increasing Medical Waste addition until either the reactor level controls start to become unstable (exceeding min. bulk density of microwave level detector) or rate of manual bag addition rates becomes difficult to sustain. (Step time: 2-4 hrs.).
7. Confirm reactor stability, when either of the limits above are reached and maintain stable operation for at least 4 hours with a stable temperature profile inside the reactor and no intermittent mechanical problems with the feeding system. (Step time: 4 hrs.).
8. With emissions monitoring equipment in-place and ready, start first 1-hour run of the stack gases while maintaining Medical Waste feed rate at a stable feed rate (Step time: 2-3 hours, depending on any calibrations or issues with the test contractor)
9. Conduct a second 1-hour emissions test while maintaining the Medical Waste feed rate stable. (Step time: 2-3 hrs.).
10. Conduct a third 1-hour emissions test while maintaining the Medical Waste feed rate stable. (Step time: 2-3 hrs.).
11. When emission contractor confirms completion of the 3rd monitoring run and data set is good, cease adding Medical Waste bags to the feed tube and run the gasifier just on woodchip for at least 60 feed cycles to ensure all of the medical waste has been consumed in the system (Step time: 2-3 hours).
12. Disable the gasifier feed system and allow internal chip inventory to draw down to Low-Low level alarm. Then, shut the unit down (Step time: 1-2 hours).

Other Test Notes:

- Grab at least two biochar samples from the residue bin during each of the two stack test runs.
- Grab at least two woodchip samples both before and after the dryer during each of the two stack test runs.
- Set aside one medical waste bag from each stack test run.
- Send all samples to a lab for ultimate and proximate analyses and forward results to emissions test contractor.
- Record all unit operating conditions (Temps, Pressures, Feed Cycles, biochar rates, etc.) during the operational test time (the SCADA is already set-up to do this and will download a data file on the local hard-drive).

Estimated Total Woodchip consumption: ~ 6 tons

Estimated Total Medical Waste consumption: ~12-14 tons

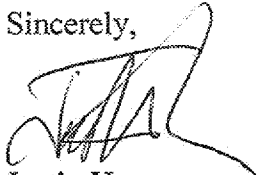
Total Estimated Unit Run Time to Completion: 30-36 hours

I certainly appreciate your consideration of this proposed plan from VES. The City of Covington has, for months now, been working not only with them but with you all to get to the testing phase of this project.

Any and all assistance you can provide will be most helpful!

Feel free to contact me via phone at 901-476-9613 or via email at jhanson@covingtontn.com if I can provide further assistance.

Sincerely,

A handwritten signature in black ink, appearing to read 'Justin Hanson', with a stylized, cursive script.

Justin Hanson

My mission is to provide positive and productive leadership that results in ongoing improved living conditions for all citizens of Covington, Tennessee

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SUPPLEMENTAL INFORMATION

Emissions Testing Parameters:

1. Source Description – Source description here is limited to a description of the sample location. The gasifier thermal oxidizer exhausts to atmosphere by way of a 24.0-inch diameter vertical stack. Two sample ports at 90-degrees are provided at a location 252 (10.5 diameters) below the stack exit and 132 (5.5 diameters) above the nearest upstream disturbance.
2. Test Procedures – Test procedures used will be those described in the Code of Federal Regulations, Title 40, Part 60, Appendix A. All test parameters will be measured simultaneously. Each test will consist of triplicate 60-minute sample runs.
 - a. Sample and Velocity Traverses – EPA Method 1– Selection of sampling locations are described in Method 1. Sample ports are installed at locations meeting the requirements of the Method. Laminar air flow at sample locations will be confirmed using the Null Pitot technique.
 - b. Determination of Stack Gas Velocity and Volumetric Flow Rate – EPA Method 2 – Stack gas velocity will be measured using an S-type pitot tube and Method 2. Pitot tube design and its orientation with respect to the sample probe and nozzle are permitted to use a correction factor of 0.84 as described in Method 2. Stack temperature measurements will be by type-K thermocouples and NBS calibration traceable digital thermometer.
 - c. Gas Analysis for Determination of Dry Molecular Weight – EPA Method 3A – Oxygen content will be measured by continuous monitoring with a calibrated paramagnetic analyzer as described in Method 3A.
 - d. Determination of Moisture Content in Stack Gas – EPA Method 4 – Moisture content will be determined from volumetric and gravimetric analysis of impinger contents of the Method 5 sample train.
 - e. Determination of Particulate Emissions – EPA Method 5 – Particulate emissions will be measured as described in Method 5 with no significant departures from these procedures. Method 5 incorporates the use of Methods 1-4. The sample train to be used will be identical to that described in Method 5 except that a cyclone may be omitted. Glass fiber filters will be used. A stainless probe liner and nozzle will also be used. Reagent-grade acetone will be used to recover samples from the filters.
 - f. Determination of SO₂ Emissions – EPA Method 6C – SO₂ emissions will be measured as described in Method 6C by directing a conditioned gas sample to a TECO Model 43C (or equivalent) pulsed fluorescence analyzer as described in the Method. A sample will be extracted from the source by way of a stainless probe, heated sample line, minimum contact moisture knockout trap, glass wool filter and vacuum sample pump. The SO₂ analyzer will be calibrated prior to use within the expected range using SO₂ standard in N₂. Zero and span checks will be performed following each 60-minute sample run. Calibration and post-run span checks will be made by introducing calibration standards at the inlet of the sample probe.
 - g. Determination of NO Emissions – EPA Method 7E – NO will be measured by continuously directing a conditioned gas sample into a TECO Model 42i (or equivalent) chemiluminescence NO_x analyzer as described in the Method. A sample will be extracted from the source by a stainless probe, heated sample line, minimum contact moisture knockout trap, glass wool filter and vacuum sample pump. The NO_x analyzer will be calibrated prior to use using gas standard NO in N₂. Zero and span checks will be performed following each 60-minute sample run. Calibration and post-run span checks will be made by introducing calibration standards at the inlet of the sample probe.

- h. Determinations of Visible Emissions- EPA Method 9 – Opacity readings will be made simultaneously with and for the same duration as the particulate measurements. Copies of visible emissions records and VE reader's certification will be appended to the final report.
- i. Determination of CO – EPA Method 10 – CO will be measured by continuously directing a conditioned gas sample into a TECO Model 48i (or equivalent) gas filter correlation CO analyzer as described in the Method. A sample will be extracted from the source by a stainless probe, heated sample line, minimum contact moisture knockout trap, glass wool filter and vacuum sample pump. The CO analyzer will be calibrated prior to use using gas standard NO in N₂. Zero and span checks will be performed following each 60-minute sample run. Calibration and post-run span checks will be made by introducing calibration standards at the inlet of the sample probe.
- j. Determination of Total Reduced Sulfur Emissions – EPA Method 16A – An integrated gas sample will be extracted from the stack. The SO₂ will be removed selectively using a citrate buffer solution. The TRS compounds will then be thermally oxidized to SO₂ and captured in impingers containing 3% H₂O₂. The samples will be titrated using BaCl₂. This Method will be a combination of the sampling procedures of Method 16A and the analytical procedures of Method 6. Although this Method normally consists of triplicate 180-minute sample runs on a GC in order to have a statistically valid number of GC injects. This 60-minute sample run selected for investigation should be sufficient.
- k. Determination of Total VOC – EPA Method 25A – VOC (as Carbon) will be measured using a calibrated TECO Model 51 (or equivalent) heated flame-ionized detector to continuously monitor VOC concentrations on a wet basis. The sample will be directed to the analyzer by way of a PTFE line heated to 250°F. A helium/hydrogen fuel will be used to reduce oxygen synergism impact on measurements. The analyzer will be calibrated using propane standards. Instrument response will be multiplied by 3 to correct results to "as Carbon" basis per the Method. Triplicate 60-minute sampling periods will be used. A 4-point calibration will be performed initially and a calibration check at zero and mid-point during each 60-min. sample period. Any necessary adjustments to the calibration will be made after recording the response of the mid-point gas calibration.
- l. Determination of Particulate Emissions – EPA Method 26A – For HCl sampling, the impinger catch of a combined Method 5 and Method 26A sample train will be recovered. The HCl samples will be shipped to an offsite lab for analysis by ion chromatography. Quartz filters, PTFE probe liners and quartz nozzles will be used for sampling.
- m. Preparation of Calibration Gases – EPA Method 205 – Calibration gas concentrations will be prepared using cylinders of EPA Protocol 1 gas mixtures and Environics (or equivalent) gas diluter verified by Method 205.
- n. Data Acquisition – All instrument data will be recorded on a Fluke Hydra (or equivalent) data-logger at 5-sec intervals and reduced to 1-minute averages. The arithmetic average of each instrument's output will be used to calculate emissions.
- o. Calculations and Presentations – All calculations and calibration procedures performed will be appended to the final report. The summary of emission averages will be tabulated and appended to the final report. Typical Appendices will be:
 - i. Sampling Data
 - ii. Analyzer Data Logs
 - iii. Calibration Data
 - iv. HCl Analysis (DAT)
 - v. Fuel Ultimate and Proximate Analyses
- p. Ultimate and Proximate Analyses of Unit Feed Streams – At least two samples of the feedstock entering the gasifier will be secured and sent to an offsite laboratory for Ultimate and Proximate analysis.

3. Updated Mechanical Drawings of the Unit – See attached set of P&ID's.
4. Material and Energy Balances – See attached summary table.
5. Proposed 80/20 Woodchip/Medical Blend – The current system in Covington was originally designed to operate as an 80/20 blend of woodchip to biosludge. The limiting factor with this design was the moisture content of the biosludge (~80% H₂O). The biosludge feeding system was a direct-injection design using a progressive-cavity pump that fed the sludge into a rotary mixer just upstream of the feed dryer. Adapting the feeding system to accommodate medical wastes will likely require some engineering review and redesign to ensure the conveyors and augers in the feeding system can adequately accommodate the physical size, volume and material properties of the “as-received” medical waste bags. One of the objectives of this trial run is to demonstrate that the emissions profile of this medical waste/chip blend is at least consistent with prior emissions profiles submitted to the State. Also, given that the medical waste will have less moisture content, its rate-limiting properties will need to be evaluated over time. My initial engineering review determined that the 80/20 blend was feasible based primarily on the limitations of the SC-200 auger and the relative size difference between woodchip, sealed plastic bags weighing 3-5 lbs. each, and the flight spacing design of the auger itself. Should the current horsepower of that auger be found sufficient to cut the sealed bags into smaller pieces and squeeze larger pieces through the outlet without jamming, then VES could consider increasing med-waste processing rates and adjust their permit accordingly. However, as previously mentioned, there is very minor chemical difference between woodchip and medical waste based on the Ultimate Analysis (C-H-O-N-S). The emissions profile is largely dictated by the ultimate analysis of the feedstock. If that analysis does not change significantly with the ratio of chip to medical waste, then the emissions profile will not change significantly either.
6. Medical Waste Weighing Provisions – A calibrated weigh scale will be placed near the inlet feed hopper. An operator will be stationed there during the testing that will log weight and times of each bag added into the unit. These logs will be included in the final report. We have successfully used this procedure in the past when testing other supplemental feedstocks and should be wholly adequate for this test.
7. Woodchip Feed Calibrations – The normal operating procedures involve periodic calibrations of the feed auger output. This simply involves catching a feed cycle (auger “on” time) into a container while the unit is operating normally. This is most typically done with 3-4 capture samples and the weights averaged. The HMI screen has an operator-entered value of the average, which is used to totalize daily and hourly the chip consumption rate. In the past, we have matched this value with weight tickets of chip delivery trucks and have found it to be quite accurate at monitoring chip consumption. One of our Operator training procedures involves looking for consistencies in this real-time chip consumption rate from hour-to-hour to identify potential system problems.
8. Plastic Content and Emissions Profile Changes (Worst-Case Issue) – As mentioned previously, plastic content in medical waste is not a “worst-case” factor as non-chlorinated plastics are simply additional Carbon and Hydrogen converted in the gasifier to fuel gas that is burned in the thermal oxidizer. There will be no detectable chemical difference in terms of HAPS between changes in the C-H-O ratio fed into the gasifier. The thermal oxidizer has a real-time O₂ sensor that measures the excess O₂ in the stack gases and records the value. If additional C-H enters the gasifier (in the form of additional plastic content, for example), the levels of H₂, CH₄, CO, and some other combustible fuel gases will increase. These gases will all be combusted when brought to 1,800°F in the presence of excess O₂. The combustion controls on the thermal oxidizer automatically adjust input air to consume the additional fuel. As for permit limits, the C-H-O content entering the system, whether it be from medical waste or from woodchip will emit the stack as CO₂ or H₂O with a relatively small amount leaving with the biochar. The only HAPS limit there should be CO, which is part of a normal combustion point-source permit. Some part, if not most, of the total S and N entering the system has the potential to emit as SO₂ and NO_x, which also have limits of a normal combustion point-source permit.
9. Trial Runs and Unit Downtime – Our request for the trial run is to be allowed at least one 12-hr shift to heat the gasifier and thermal oxidizer to steady-state temperature using just commercial paper chip

as the fuel source. The gasifier will then be stopped and blocked-in. Crews will be allowed to go back to their hotels/residences and return the following morning. The gasifier will then be restarted on woodchip and should recover back to steady-state temperatures within a matter of a few hours. This is called the "Hot-start Procedure." Alternatively, an operator could maintain the gasifier at reduced rate overnight so that when crews come in the next morning, the medical waste introduction could begin earlier. The emissions contractor should arrive that morning and begin situating their equipment while the gasifier is rewarming. You are correct that each stack test run will involve 3 one-hour tests. So, we revise our proposal to allow for 5 hours to conduct each test and will plan to conduct each test back-to-back in a single day. We have successfully done this before at this facility. Alternatively, we can dispense with the duplicate run since the main test will involve 3 separate 1-hour sample periods and will allow sufficient time to clear the unit out before shutting down the second day.

10. Thermal Oxidizer Operation – The thermal oxidizer has dual-fuel capability and can operate on either producer gas from the gasifier (~120-135 Btu/SCF) or pipeline natural gas (~1,000 Btu/SCF) or both at the same time to maintain a peak flue gas temperature at a controlled set-point. A stack O₂ analyzer continuously monitors and records the excess O₂ levels to ensure complete combustion of all gaseous fuels fed into the oxidizer. Prior experience has been that once the gasifier reaches steady-state temperature, the natural gas control valve automatically closes and no supplement fuel gas is needed to maintain set-point temperature. The producer gas has more than enough HHV to run the system. That is how the unit was designed to operate. Most commonly, we operate at between 6-8% excess O₂ and between 1,700-1,800°F. We don't control the combustion air blower flow to run at a fixed excess O₂ set-point because the time-lag is less favorable for direct loop-control. We have found setting the combustion air blower to a temperature set-point on the outlet of the combustion chamber with a low-acting proportional control function to work best. The temperature and excess O₂ will naturally oscillate a little to accommodate minor fluctuations in minute-to-minute producer gas generation rates.